

A PARAMETRIC MODELING OF CONSTRUCTION FRAME IN YINGZAO FASHI

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ABSTRACT

Parametric Design is a new process that is used dynamic library objects. These parameters can adjust the shape and size of objects for not just once-off static modeling. In the traditional architecture, construction frame is the amazing skill in geometric forms. This study makes the parameters into systems of the palace-halls in the Yingzao Fashi, and then the traditional architecture of construction information and knowledge can be discussed in depth. Furthermore, it can be increasing the efficiency of automatic modeling.

This study applies the tool of BIM which includes parametric design, automatic modeling, Geometric Description Language (GDL). The processes of this study is divided into two sectors, first will be the analysis of the different styles in the palace-hall, and explore the impact in scale rules and bracket types. We define the parametric element and create parametric matrix with integrating the analyzed relational construction frame and geometric dimension. Then coding the GDL programming to simulate the palace-hall frame objects. These parameters include the parametric rules, relationships between objects, geometric dimension, and objects category... etc. The automatic modeling program not only can present complex styles by different parameters, but also investigate the benefit of automatic modeling.

The achievement of this study includes three parts. First part is derivation of parametric matrix, it present the relationship of each parameters. The second part is coding the prototype of automatic modeling program; this program can be used as the basic investigation view of the palace-hall. The third part is building the database of construction frame. These results will be an important stage of this study; also they can be used as a traditional construction frame reference for education.

KEYWORDS: Parametric Design, BIM, Yingzao Fashi, Structure Frame, GDL

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INTRODUCTION

BIM can efficiently analyze and construct a model, and analyze parameter; it can be used as an automatic tool for modeling. In recent years, BIM issues have appeared, it has become a trend which be used in construction projects. BIM is apply to public construction management recently, and committed to the popularization. Yingzao Fashi is the first detailed description of the China Architectural Engineering practice of official writings. It rigorously standardized methods and standards of constructing, and effect of other related books. It after all is a representative book of construction method in China.

Today the importance of monument has been substantial and widespread than before. Monument is not only rare, special and has highly historical value, but also has rich information of political, economic, culture, art, religion etc. in ancient society. How to save and aggregate the data becomes an important issue. Combining with

BIM, its effectiveness will large increase. The method of data records not only is a breakthrough, update and change data can be more efficient.

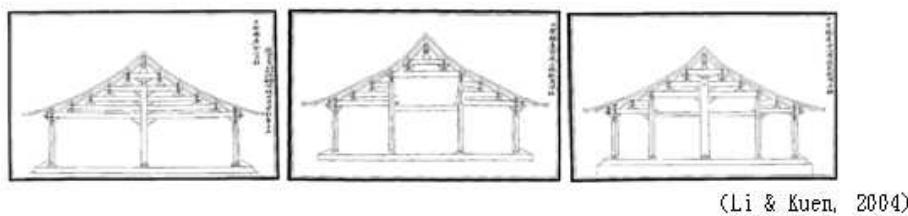
The first step would be the analysis of the structure frame in Yingzao Fashi. Sort out the relationship between columns and beams. Secondly, according to the relationship to build the parametric system. Thirdly the use of GDL programming function to simulate the frame structure pattern, and investigate the efficiency of the parametric automatic modeling. This study process will be defining the parametric elements and analyze the structure frame to set up the relationship and the rules of the parameter, adding geometric、programming and category...etc., to the element to create different group of forms depending on the settings.

This study achievement will be derivate the combination of forms and parametric list of the frame structure, finishing the prototype of the structure frame simulative program, preliminarily investigate the combination of forms in Yinzhou Fashi structure frame, it can be used as a traditional structure frame reference for education.

RELATED WORK

Yingzao Fashi

Yingzao Fashi is a prescriptive guide for building construction (Feng, 2006; 洪宇, 蒋玉川, & 四川大学, 2013). Most of the architectural forms were created by Yingzao Fashi, providing the intangible cultural assets. China Architectural Culture in Song Dynasty reached its peak, there is not much breakthroughs in Yuan, Ming, Qing (Feng, 2006; 邵惠鑫, 宋绍杭, & 徐鑫, 2009). There are many types of palace in Yingzao Fash. From Architectural History standpoint, palace building has a government standard system of planning and design, the form and appearance style of palace in Ming, Qing have not allowed any changes (张学芹 & 刘畅, 2007). As dynasty goes on, the scale of palace complex has been shrinking, including other buildings. Both changes are very similar. Thus, palace building is indicative in Chinese Traditional Architecture (王贵祥, 2005). Data access of this study is unlike previous, we create a library of parametric objects which are designed for modelling traditional architectural elements from survey data. Structural concept in Yingzao Fashi has great idea in the architectural construction, it create a little architectural simple units into ever-changing (罗汉军, 2007). This study investigates the structure of beams and columns, and consider the characteristic of parameters Figure 1. (罗翔, 吉国华, & 南京大学建筑学院, 2009)



(Li & Kuen, 2004)

Figure 1: The Type of Beams and Columns in Yingzao Fashi

BIM

Building Information Modeling is a coordinate, internal consistency process of designing and construction project and it is kind of calculable data (Kota, Haberl, Clayton, & Yan, 2014; Rafiq & Rustell, 2014; 张晔, 2011), this system can increase design quality, decrease construction cycle, reduce design costs, and also integrates various of other specialized

design (Kensek, 2014; 张泳 & 王全凤, 2008), for the purpose of today, BIM related studies and applying are mostly referred to architectural management, but it also can construct project data and integration mode, and under the project data mode, it developed project planning strategy and construction control system (Boeykens, Santana Quintero, & Neuckermans, 2008; Inyim, Rivera, & Zhu, 2015; Rafiq & Rustell, 2014) to fulfill the project planning and construction control (陳怡兆, 2009).

The process of project management considers different stages of project management and different needs of the users (刘爽, 2008; 林祐正, 洪佳君, & 陳彥貝, 2014; 陳維東, 黃盈樺, & 林祐正, 2014; 蔡政軒, 2014; 簡睿永 & 杜功仁, 2014). In this study, simulates modeling project management in the aspect of BIM, this system is efficient for creating files and the integration of Building information modeling and analyzing structure frame.

The data of the old building is important to Heritage conservation, in the past, the Heritage conservation is by paper, table, writings, picture and so on (孙卫新, 2013; 李越, 刘畅, & 王丛, 2009), but these methods has many problems like the enormous data, the inaccurate data, data uneasy to reach. This study provided a new way of old building restoration for the monument, the model can be a part of the data to be restored, it can be opened at any time and be read when the heritage conservation is in process. Using the extended profile feature (罗翔 et al., 2009) and create the data needed for this study, to achieve the expansibility of the data storage and the addressable data (孙卫新, 2013).

By using BIM, the model can simulate the data of a real building(林雅媚, 2012; 曾冠霖, 2013), using the program to model the 3D building for design or research, when the model is modeled, the evaluation and analysis system can be carried out (Donelan, 2001; Inyim et al., 2015; Laiserin, 2001), this study attempt to study relationship varieties of unit type to create parameter(陆蕾 & 南京大学建筑与城市规划学院, 2011), to research the modeling method for the monument, and investigate the groups in the aspect of parametric modeling advantages and limitations.Regarding the use of parametric modeling for traditional architecture, the traditional architecture has a feature of regularization and architecture modulus, at this point, we can find some proportion relationship between the scale of the parts of the architecture, and these relationships can be used as a modulus for parametric modeling (范素玲, 沈裕倫, & 洪崇璋, 2013).

This study aims to research the method of adding additional data in traditional architecture structure 3D modeling, the structure additional data can directly store in the graphics library, and the data is stored as a part of the model itself (孙卫新, 2013). This study uses field information to achieve expansibility and settable data storage Figure 2.

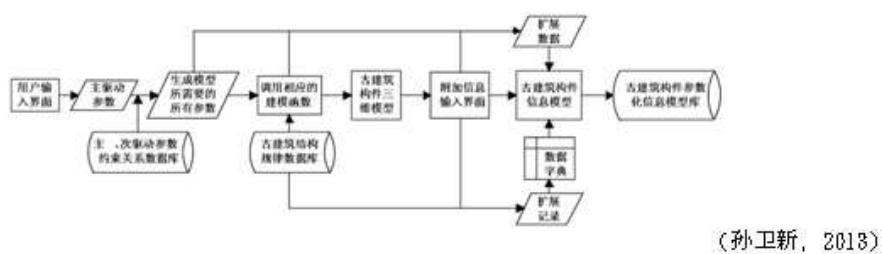


Figure 2: A Frame of Construction Information Platform System Model Design

Parametric Design

Parametric design is a computing logic that can quickly calculate the result (Murphy & Scott, 2011; 蔡宗璋, 2013). The level of parametric design is a structure that is based on the characteristic of the object, data and image, according to 2D geometric drawing and 3D modeling, to create different parametric levels (徐延甯 & 孟祥旭呂琳, 2004). In this study, using a variety of variables to develop a design method (Donelan, 2001; 翟炳博 & 杜小辉, 2010). And through parametric system extend to qualitative modeling and modeling method, to define the rules of groups and constraint (罗善元, 2012), using geometric constraint to proceed qualitative modeling and modeling (邵晨曦, 欧阳扬, 杨明, & 王子才, 2007). The parametric technology can also combine Microsoft visual C++, Microsoft Access to investigate the relationship between data structure and data transition (孙成通, 辛琳琳, & 韩虎, 2006), using modeling parameter to investigate parametric modeling system. For the method of the parameterization of the structure frame, define the frame structure as $D \cdot D = (C, d)$, C is for the form; d is for detailed description. And the combined beam and column form is $D_i = (C_i, d_i)$ and $D_{i+1} = (C_{i+1}, d_{i+1})$ these codes will be bases of the form transformation(I.-K. L. Andrew, 2004). And import

$$C_{(i+1)} = [C_i - p(t(A))] + p(t(B)) \quad (1)$$

p for corresponding the parameter, A and B is the form of the model, to let the parameter more accurate Figure 3 (I. Andrew & Li, 2004). The library includes the data in the parametric models, and these libraries are disposable but dynamic, because of the parameter, the sizes and forms can be mutative (Dore & Murphy).

METHOD

Overall Structure

The aim of this study is to set up a parametric system of construction frame in Yingzao Fashi, the parametric construction frame can be converted into different types of combinations, and by doing so, the efficiency of this system can be analyzed. The structure of this study is divided into four parts:

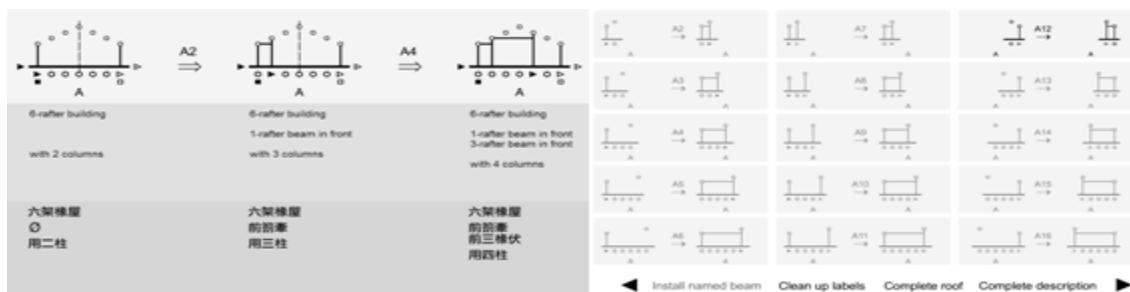


Figure 3: The Aspect Simulation of Parametric Models

The first part is to analyze the construction frame in Yingzao Fashi and some relevant information, to create the library in this model, the library includes property data, chai fen rules¹ and spatial data (the spatial layout and section of the palace). The second part is BIM, combining the result of the last part as a data of the BIM to create part four and five. The third part is automatic modeling, sorting the elements and parametric modeling, the overall parametric system will mainly to study the column forms, there are four type of forms (3 bay to 13 bay, four types of layout, double/single interior

¹ chai fen rules is standard component scale in Yinza Fashi

bracket, with/without *zhou za*²) to choose, and integrate the elements to create the whole structure frame. The fourth part is to parameterize, the parametric system can control the relationship between elements, to present different groups Figure 4.

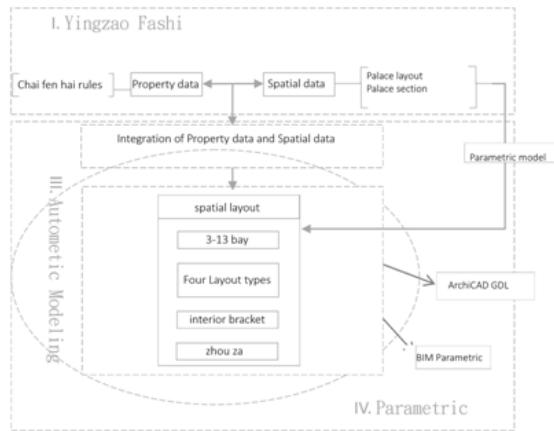


Figure 4: Overall Structure

Construction Frame

The regulation of buildings, all in accordance with the *chai fen* rules. *Yingzao Fashi* has pointed out, the scale of the building, has to follow the rules of *chai fen* rules. “*Chai*”, is a guideline of using construction material when constructing a building. A “*fen*” is 1/15 section height of the *chai*, there are 15 *fen* in height and 10 *fen* in width in *chai* (Table 1).

Table 1: Summaries of Palace Materials

Spatial type	Building scales	Bay	Fen
Palace	One	9-11	0.6
	Second	5-7	0.55
	third	3-5	0.5

The Palace Spatial Layout Types

According to the *Yinzao Fashi* construction frame rules, the number of columns and the length between the columns has six different types, the interior bracket determines the length between the columns, the length of single interior bracket is divided into two equal parts and double interior bracket is trisection, in double interior bracket the types is based on the length among the three parts, and two kinds of layout types determine the number of columns.

According to the number of the beam, there is eight kinds of forms, in these forms there are with and without middle column. The rafter³ determines the combination and number of the beam. In *chai fen* rules, the beam has six kind of sizes, according to the different lapping method, to make things more convenient. This study simplifies the column to a rectangular column.

² adding an additional Cloister to the main building

³ the wood that mounted on the roof to support the roofing material

Parameterize

The process of the BIM parameter of the Yingzao Fashi construction frame is shown below Figure 5, BIM parameter includes geometric data, structure data, and material data so on, the data base also can be included in the model.

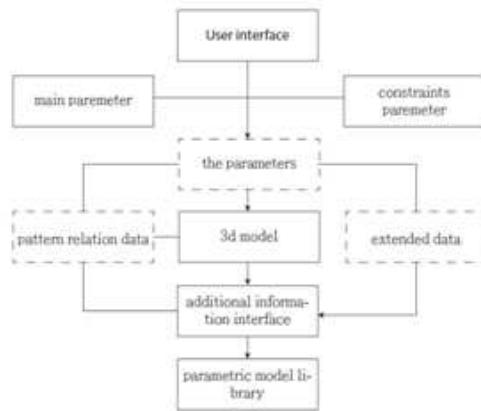


Figure 1 : The Organization Parametric Modeling Library

Parametric Matrix Relationship

The variety of the spatial layout Structure frame is influenced by the relationship by the object classification. The variable is summarized by data, and creates the parametric stage system data that will be in use; this stage of the study uses the chai fen rules of fifth to tenth bay in as objective to do parametric modeling.

Through parametric modeling and simulation, defines rules and types, using geometric constrain to create qualitative modeling and modeling. In this stage of this study, the parametric variable modeling is divided in to three parts Figure 6. The first is input variable. The second is dependent variable. The third is constant variable, by sorting out the relationship between the scales of the variables, setting the interior bracket to 20 unit of length to constrain other variable sizes.

variable	KJN	BJPN	GSN	GJ	TJD	CKJD	JSN	BJPZUD
KJN: bay	3, 5, 7, 9, 11, 13							
BJPN: interior bracket	=0 or 1							
GSN: rafter								
GJ: zhou za	=1 or 0							
TJD: site bay distance		if BPN=odd then KJD=BJPZUD*2 else KJD=BJPZUD*3			*			
CKJD: inner bay distance						*		CKJD=BJPZUD*3
JSN: depth of bay	3<JSN<KJN-2		JSN=GSN*GSUD/TJD					
GJD: zhou za distance						GJD=TJD*2/3		
BJPZUD: interior bracket distance	20							

Figure 2: Parametric matrix relationship

RESULTS

This study code parametric program with ArchiCAD GDL. First, create a column element call “c1”, then build a library of parametric objects. These library objects are dynamic and have parameters that can alter the shape and size of objects for multiple uses and not just once-off static modelling. Enter configuration information, variable and proportion. Use the distance of interior bracket to control monolith column scales. The coordinates set (0,0) to the original point, and respectively to positive and negative quadrant set a command to import “c1” column, then automatically return to the origin. Increase KJN (bay number) parameter options, to control the overall system changes in external input data.

2D Coding

Using GDL the elements in the pattern are reproduced using a design framework based on parametric rules and shape rules. Objects are scripted with parameters making them dynamic objects that can be reused. In GDL, 2D program controls the patterns and positions of elements. Therefore, the definition of overall columns in this part has to be accurate Figure 7.

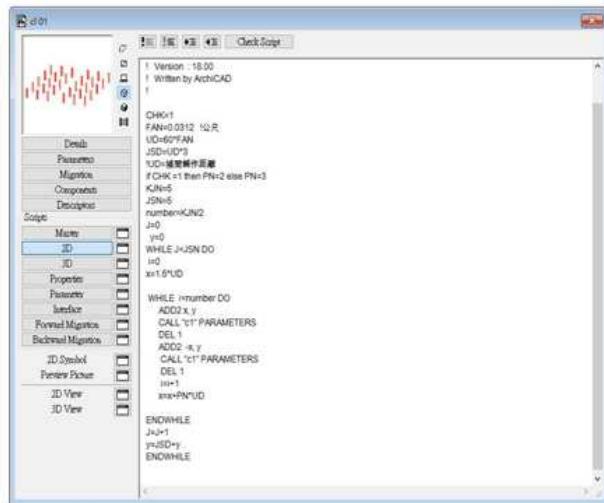


Figure 3: ArchiCAD GDL 2D program

CHK=1

FEN=0.0312 (FEN is an unit of a frame structure, in terms of the current unit is equal to 0.0312 meters, it controls the overall proportion in this relationship.)

UD=60*FEN (The length of the UD is determine by the proportion mentioned above.)

JSN=UD*3 (After the length is determined, the JSN can be decided)

If CHK =1 then PN=2 else PN=3 (The length of the overall columns is determined by UD and CHK, the KJN is controlled by the input variable)

KJN=5 (KJN is an input variable which controls the columns position in x axis.)

JSN=5 (JSN controls the columns position in y axis.)

The coordinates set (0,0) to the original point, and respectively to positive quadrant set a command to import “c1” column in x axis. DEL 1 goes back to the first step and import “c1” column at the negative quadrant.

Number =KJN/2

J=0

y=0

WHILE J<JSN DO

i=0

```

x=1.5*UD

WHILE i<number DO

ADD2 x, y

CALL "c1" PARAMETERS

DEL 1

ADD2 -x, y

CALL "c1" PARAMETERS

DEL 1

i=i+1

x=x+PN*UD

ENDWHILE

J=J+1 (It controls the position of columns in y axis.)

y=JSD+y

ENDWHILE

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D Coding

Different from 2D program, the element can be seen in the perspective in the 3D program. The 3D program is based on the 2D program. On the columns position, the z axis is added to constrain the height.

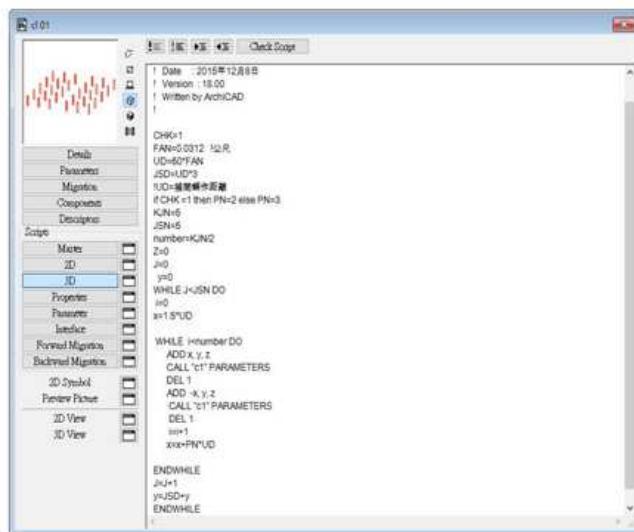


Figure 8: ArchiCAD GDL 3D program

CONCLUSIONS

In this study, we understood the feature of structure frame and information contained in Yingzao Fashi. Further analyzed the development possibility of ancient building information modeling design. Derived parameter matrix of composite style, and planted the significance of palace combination patterns. If this system is continuing research and development in the future, it can support extension information. The library which contains information about the ancient buildings, not only offer accurate information for the repair and restoration of ancient buildings, but also provide historical data for the study of ancient buildings. The ultimate goal of this study is to establish the parameters of the model library and information management platform. And the mapping data of ancient buildings can converted to three-dimensional model.

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